

# The National Earth System Prediction Capability (ESPC) Project

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# ESPC Overview

An interagency collaboration, initiated in 2010 between DoD (Navy, Air Force) and NOAA, and expanded to DoE, NASA, and NSF in 2012 for coordination of research to operations of a National earth system analysis and prediction capability.

It seeks to improve communication and synergy, for global prediction of weather, ocean, and ice conditions at weather to short-term climate variability timescales.

- Common prediction requirements and forecast model standards that enable agencies to improve leverage and collaboration.
- A national research agenda that will improve prediction across scales from days to decades.
- Cooperative demonstration projects to assess predictability of global scale high impact environmental conditions to inform S&T, R&D, and transition to operations.
- Towards an multi-model ensemble based air-sea-land coupled global prediction capability



# ESPC Goals

Build the next generation operational national environmental prediction system:

- Advance computational and environmental numerical prediction science and technology through coupled model development
- Enhance our understanding of the complex interactions of the earth environmental system through process studies
- Identify and quantify uncertainty and risk through probabilistic prediction
- Improve operational predictive capability with better skill scores and longer lead times through technology transition
- Provide insight and guidance for informed decisions in an increasingly complex and changing global human enterprise

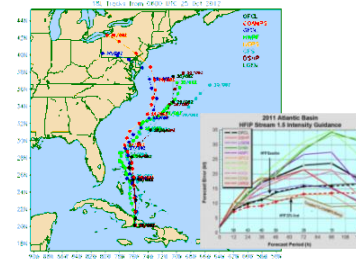
Implement an ESPC Suite across partner Operational Prediction Centers

# Collaborative Programs Across Scales

## Inter-agency Atmospheric Weather and Coupled Climate R2O Ensembles

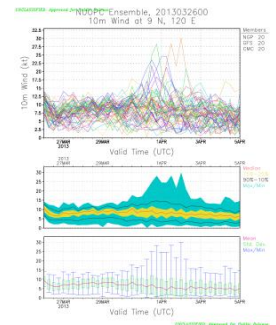
- **Hurricane Forecast Improvement Program (HFIP: 1-7 days)**

- Providing rapid improvement R2O capability for US (NOAA) and Global (Navy) Tropical Cyclone Track and Intensity
- Distributed Production Centers leverage multi-agency resources



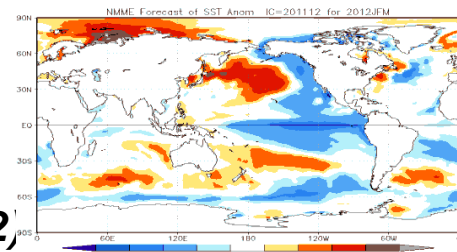
- **National Unified Operational Prediction Capability (NUOPC: 5-16 days)**

- Improving medium-range forecasts and probabilities of specific events
- Multi-model Ensembles are more accurate for longer lead times.
- Distributed Production Centers leverage multi-agency missions and resources



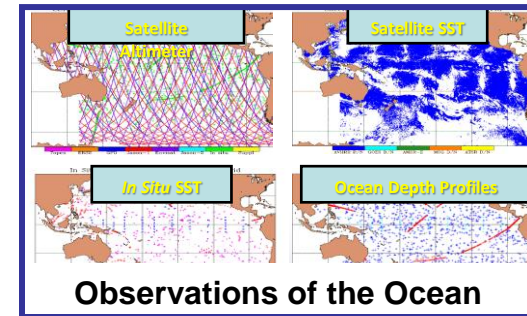
- **National Multi-model Ensemble (NMME: 3-9 months)**

- Multi-model Climate Ensembles are more accurate than any member
- Distributed Production Centers leverage multi-agency and international computer infrastructure and investments.
- Skill improves with spatial resolution - All are run at sub-optimal but best affordable resolution.
- ***Currently a Phase II research project through FY14 for higher resolution output suitable for sub-seasonal updates (Weeks 3-12)***

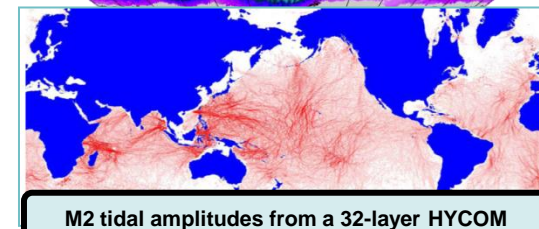
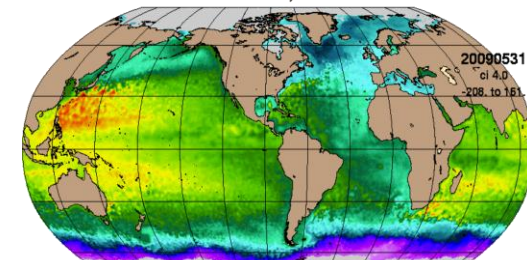


# Collaborative Community Models

- The **HYCOM** ocean model and data assimilation system have been developed to provide daily, weekly and extended forecasts of the global ocean conditions at high (~3km) horizontal resolution.
- HYCOM and **WaveWatch-3** have both been awarded the National Ocean Partnership Program (NOPP) Excellence in Partnering Award and engage with consortia consisting of Federal, university, and international partner institutions
- Both the U.S. Navy's and NOAA's ocean forecast systems use HYCOM and WW-3 and they are used extensively in academia for continued research
- Code repositories for **HYCOM** (NRL-Stennis), **WaveWatch-3** (NOAA-NCEP), **CICE** (Los Alamos National Lab), the **Land Information System (LIS)** (NASA-GSFC), and **Noah** (NOAA-NCEP) allow universities and federal partners to openly access the latest improvements from community-based development while maintaining configuration management and documentation



## Predicted Ocean State





# Why Coupled?

## Short Range Prediction

- Tropical Cyclone intensity & track is dependent on ocean temperature and the depth of warm/cold water.
- Littoral/coastal prediction (Land-breeze/sea-breeze, sensor performance, abrupt wind/temperature changes at the north wall of the Gulf Stream, etc.)
- Sudden, gale force cold air surges (South China Sea, Ice shelf, etc.)

## Medium Range Prediction

- Monsoon onset, breaks and intensity, Active tropical convection periods (Madden Julian Oscillations or MJO)
- Polar low pressure systems (resembling hurricanes), Blocking high pressure systems causing intense flooding and droughts
- Ocean fronts and eddies

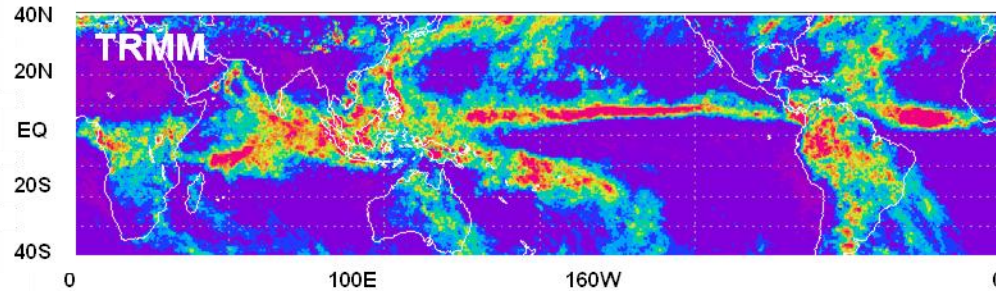
## Long Range Prediction

- Teleconnections or inter-global weather and climate links such as El Nino, Seasonal TC patterns, Ocean SST patterns, climatology shifts & anomalies)
- Arctic ice dynamics, droughts & floods, regional fires/smoke

# NAVGEM/HYCOM Rainfall

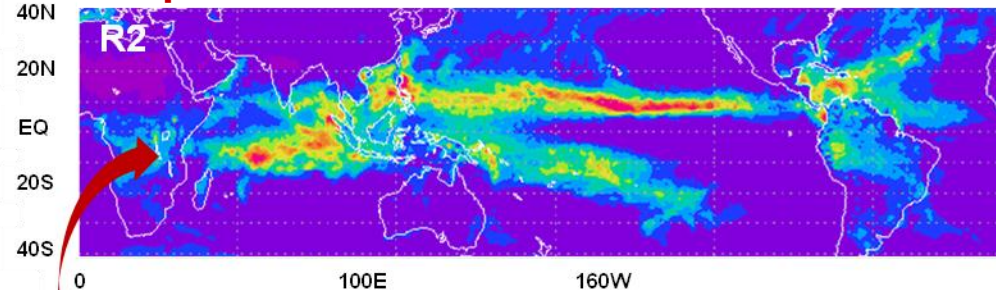
## “Daily Averaged Forcing Run R2”

### November Mean Rainfall

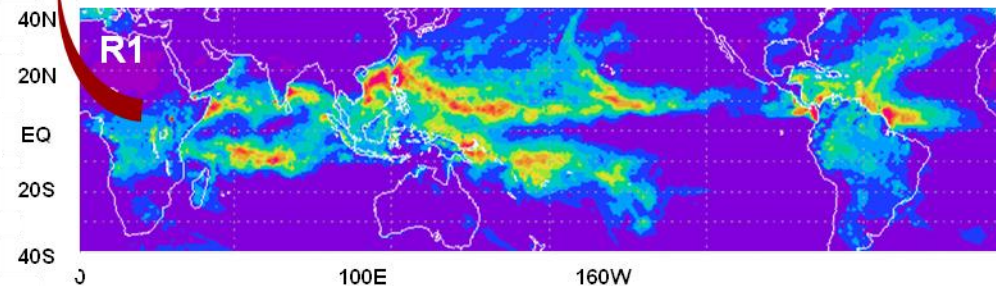


TRMM

**R2 has improved representation of Indian Ocean rainfall compared with the fixed SST run R1**

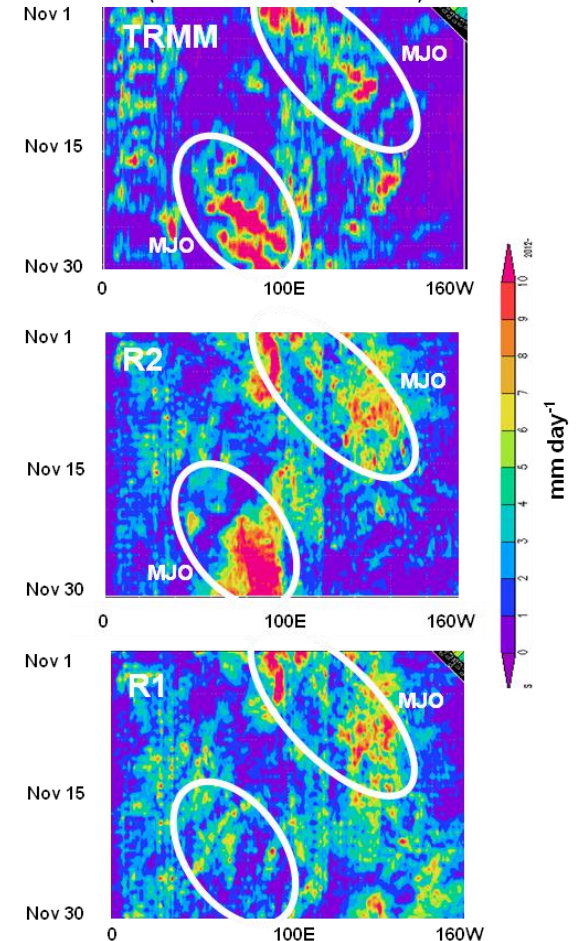


**NAVGEM R2 run - hourly ingest of HYCOM Exp 24.1 SSTs**



**NAVGEM R1 run - Fixed NCODA SST (Control)**

### Rainfall Hovmöller Diagrams (rainfall between 5S – 5N)

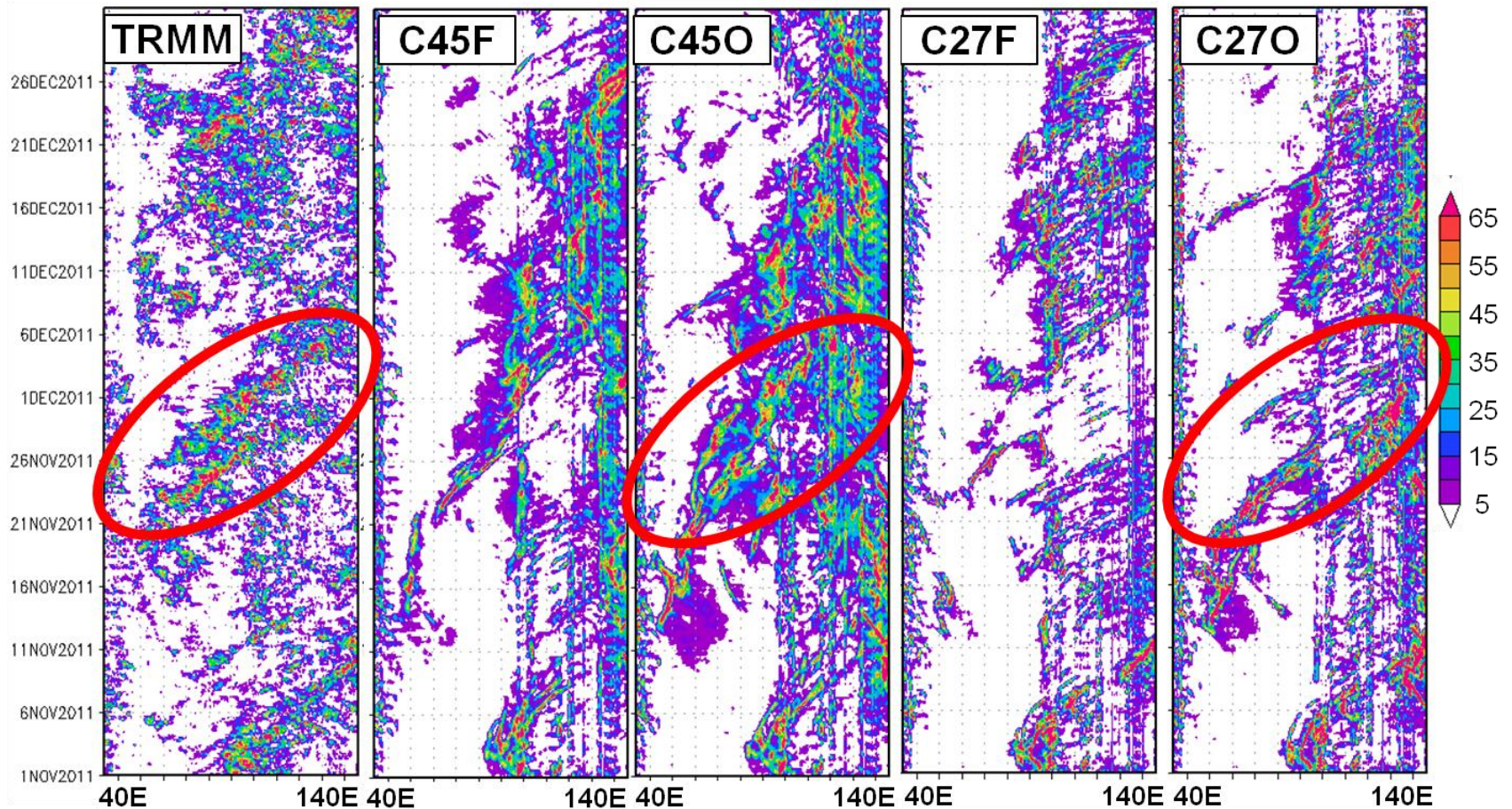


*Reynolds, Hodyss, et al. 2013*



# COAMPS/NCOM Equatorial Variability

## Precipitation (mm/day) for 5S-5N

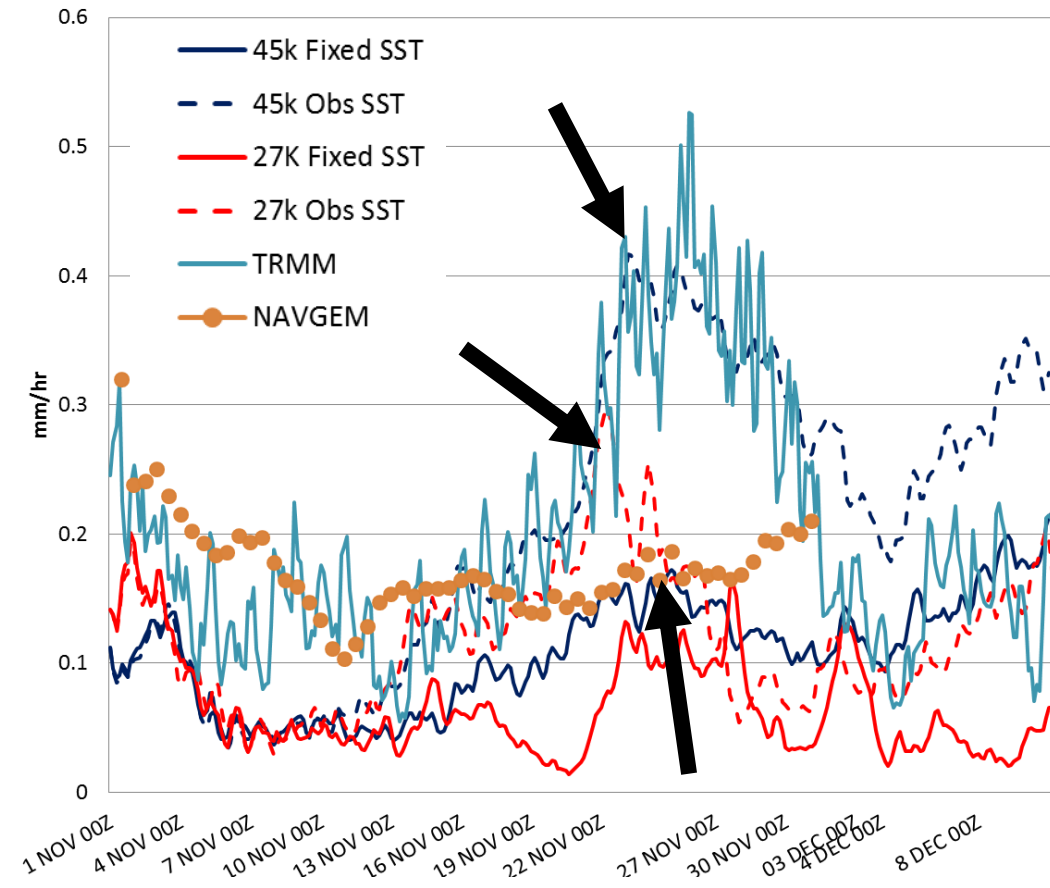


- Remarkably good late-NOV MJO signature, esp. for C45O
- NAVGEM (not shown) does not capture late-NOV MJO *Chen, Doyle, et al. 2013*



# Precipitation Time Series (mm/hr)

## Tropical Indian Ocean



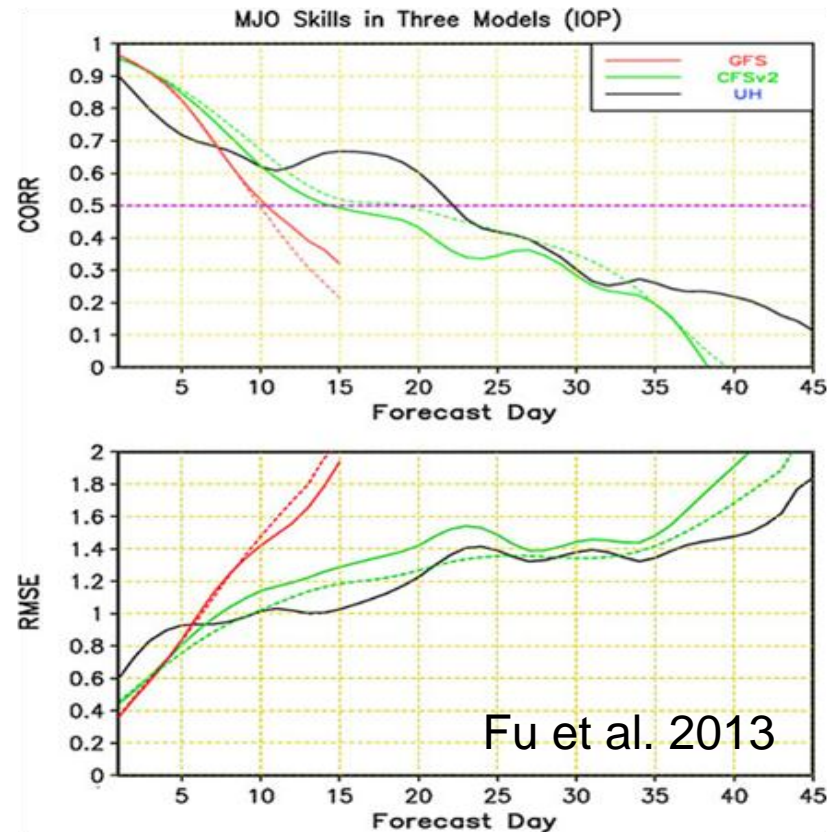
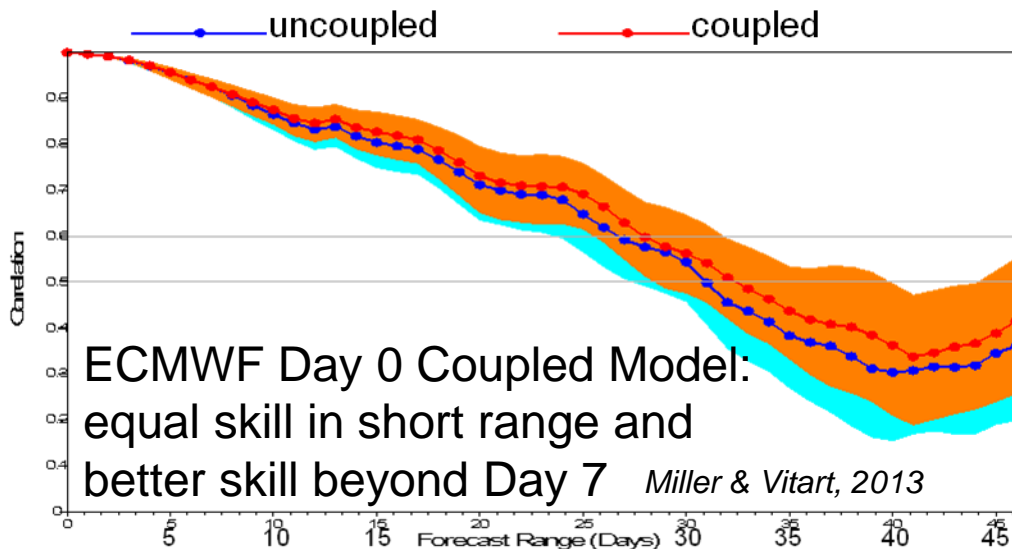
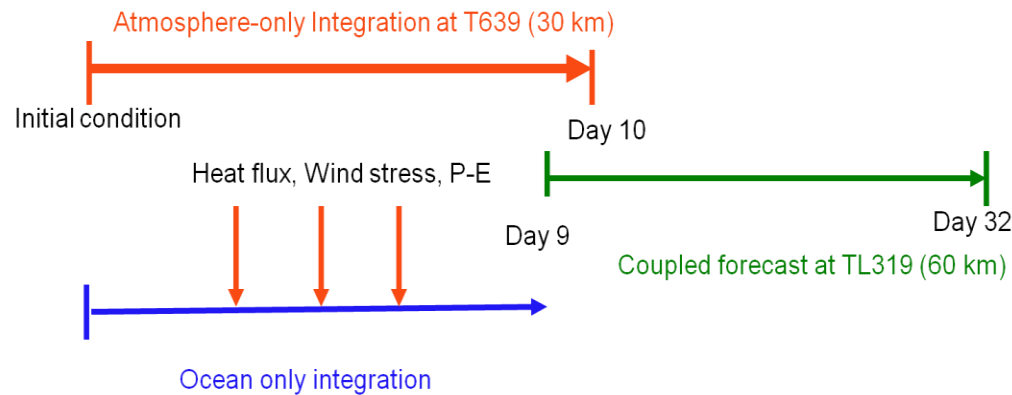
**C45O (dashed blue) good at catching upswing in precip in late Nov.**

**C27O (dashed red) also shows increase in precip, but not as strong as C45O**

**Fixed SST runs (C45F, C27F, and N37F) show much weaker late-Nov. precip increase**

# Short/Medium Range Coupled Ensemble Prediction System

## Current ECMWF Monthly Forecast System



Exact approach to optimally evolving the SST in a forecast is still a research challenge.

# Earth System Prediction Suite (ESPS)

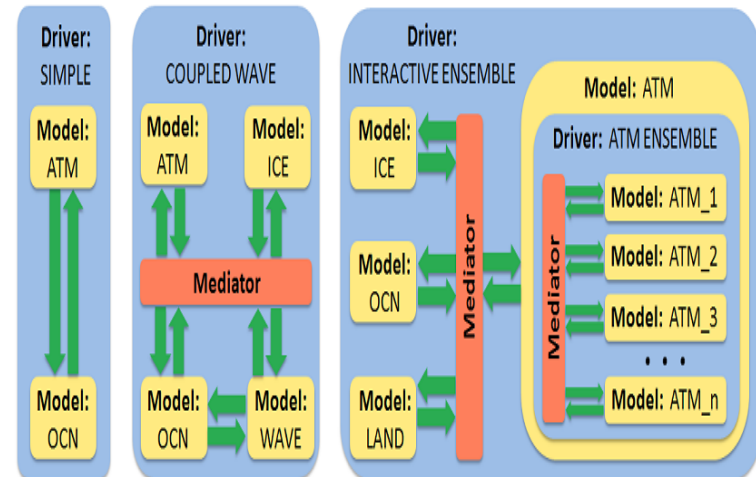
## Common Model Architecture

ESPS is a collection of Earth system component models and interfaces that are interoperable, documented, and available for community use. ESPS is intended to

- formalize code preparation for cross-agency use
- simplify “toolkit” code selection for the broader research community
- focus on coupled modeling systems
- leverage legacy investments from NASA, NOAA, NSF, DOE, and Navy
- bridge climate (CESM) and weather (ESMF) scales
- establish “plug-and-play” implementation via the NUOPC interoperability layer.

ESPS codes:

- are NUOPC-compliant
- include model documentation
- have clear terms of use
- include compliance checking and tests for correct operation across the development community.



<http://www.earthsystemcog.org/>

Deluca2013



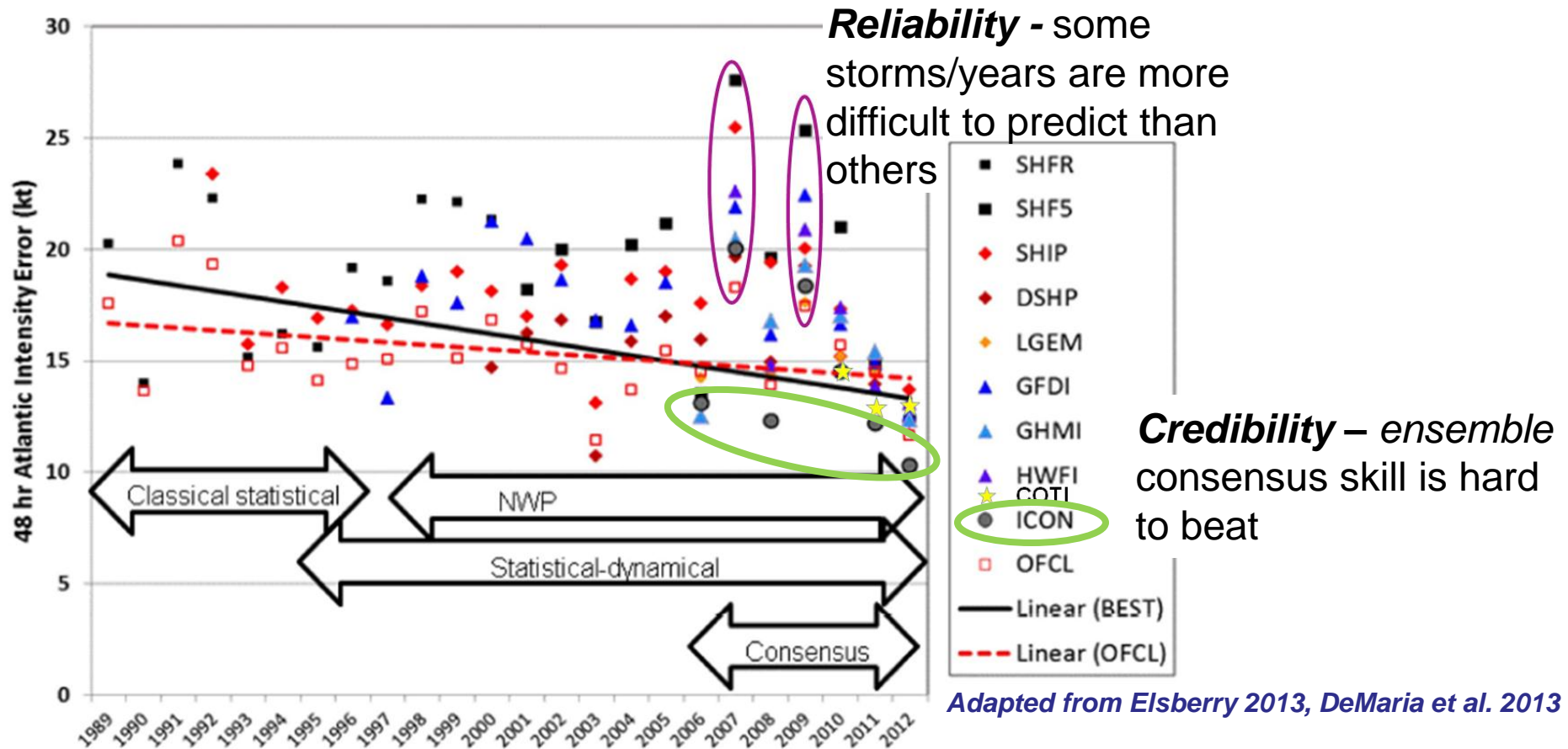
# What Do We Gain from Multi-Model Ensemble Prediction?

Practical approach to estimating and understanding forecast uncertainty due to initial conditions/observation errors, model formulation and numerical uncertainties

- Multiple instances of single models can reduce initial condition error
- Single model ensembles are often over-confident (low spread) and have persistent error modes and biases
- Multiple model ensembles reduce model and numerical errors
- Each center can leverage distributed computing resources for a larger number of members

Result is a better prediction and an understanding of the uncertainty in the prediction and a natural focus for multi-institutional partnership

# Ensemble of Intensity Forecast for Individual Hurricanes

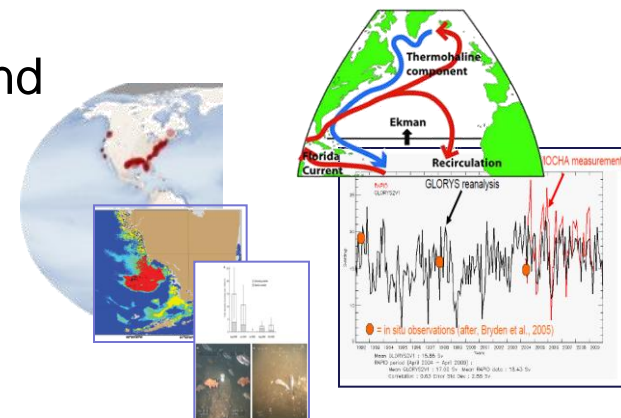
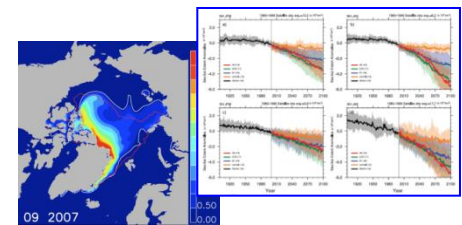
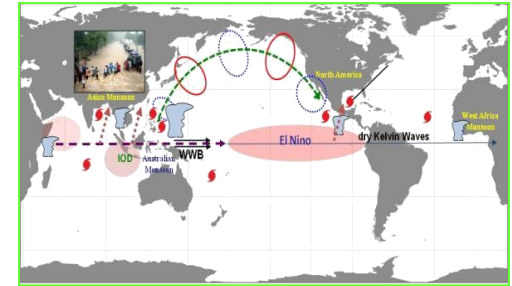


Non-homogeneous sample of Atlantic 48-h intensity forecast errors (kt) for tropical storms and hurricanes provided by various techniques and during the 1989-2012 seasons. (DeMaria et al., 2013). Using the best-track positions as a hindcast for a 2002-2009 sample indicates that some intensity improvement may be achieved if track forecasts continue to improve, but further improvement in the intensity forecast itself is also needed.

# ESPC Demonstration Projects

## Assessing link from Predictability to Prediction at S2S and ISI Timescales

- Extreme Weather Events: Predictability of Blocking Events and Related High Impact Weather at Lead Times of 1-6 Weeks (**Stan Benjamin**)
- Seasonal Tropical Cyclone Threat: Predictability of Tropical Cyclone Likelihood, Mean Track, and Intensity from Weekly to Seasonal Timescales (**Melinda Peng**)
- Arctic Sea Ice Extent and Seasonal Ice Free Dates: Predictability from Weekly to Seasonal Timescales (**Phil Jones**)
- Coastal Seas: Predictability of Circulation, Hypoxia, and Harmful Algal Blooms at Lead Times of 1-6 Weeks (**Gregg Jacobs**)
- Open Ocean: Predictability of the Atlantic Meridional Overturning Circulation (AMOC) for Improved Weather and Climate Forecasts (**Jim Richman**)

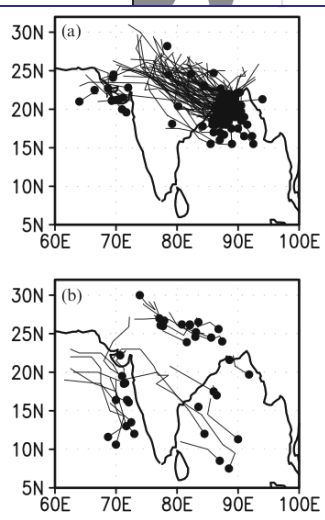
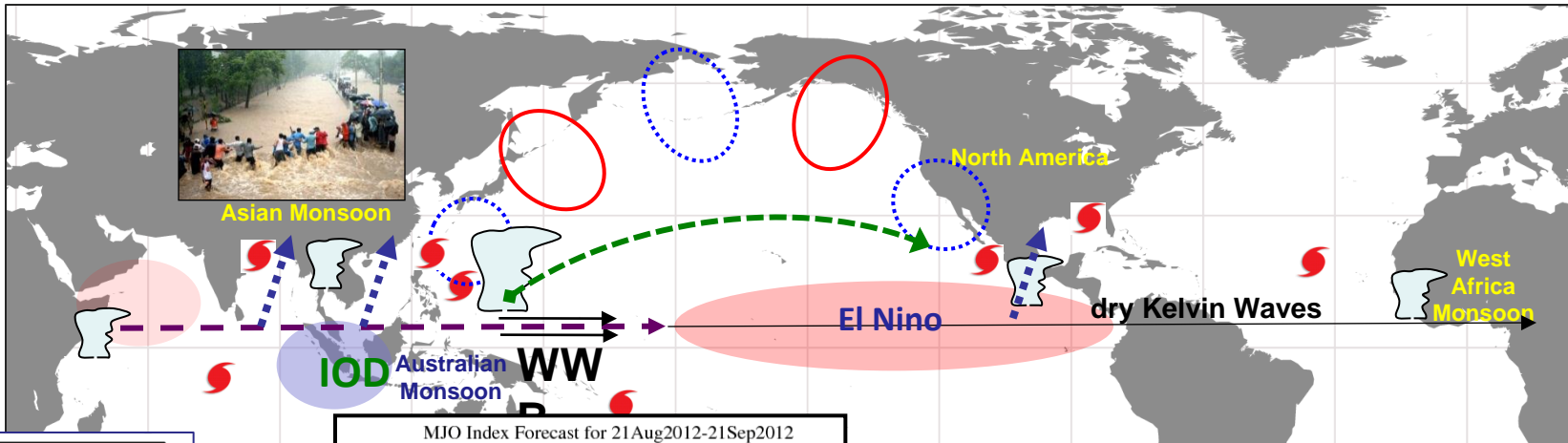




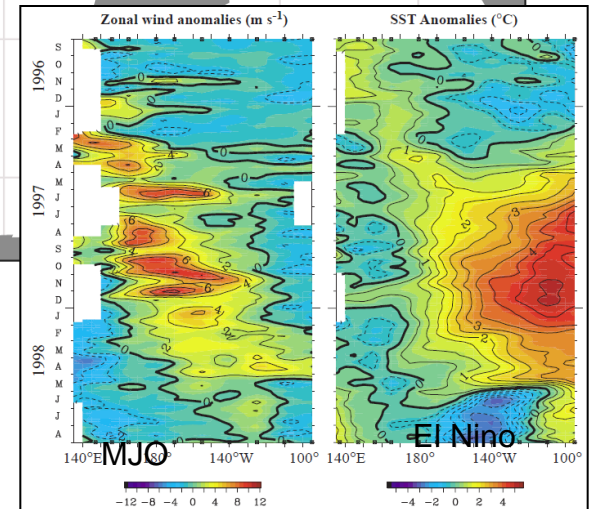
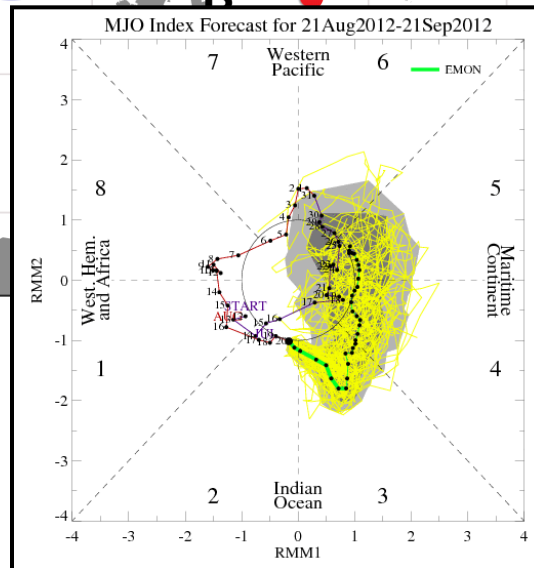
# Extending the Forecast

## Global Impacts of MJO

Maloney and Hartmann (2000)

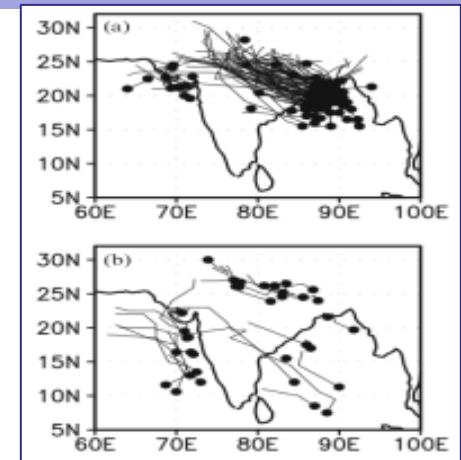
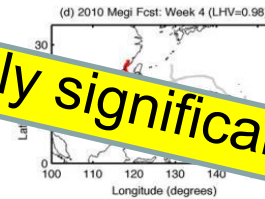
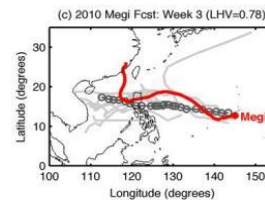
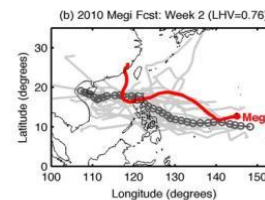
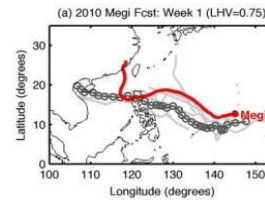
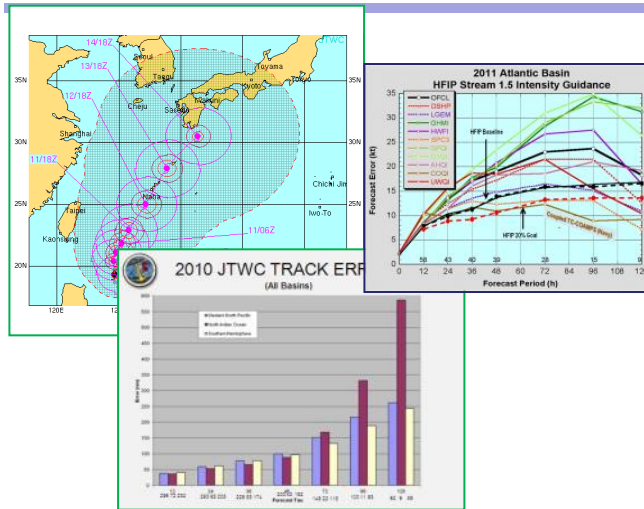


Goswami et al (2003)



McPhaden (1999)

# Example: Typhoon Probability/Track

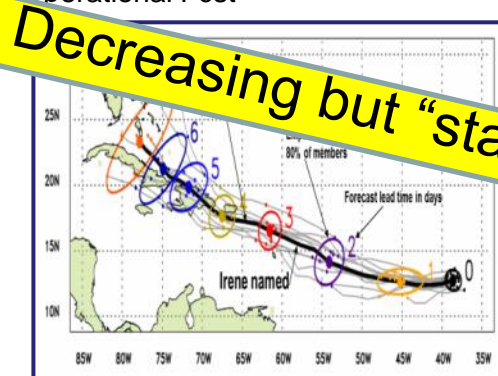


Goswami et al (2003)



Maloney and Hartmann (2000)

5-day Operational Fcst



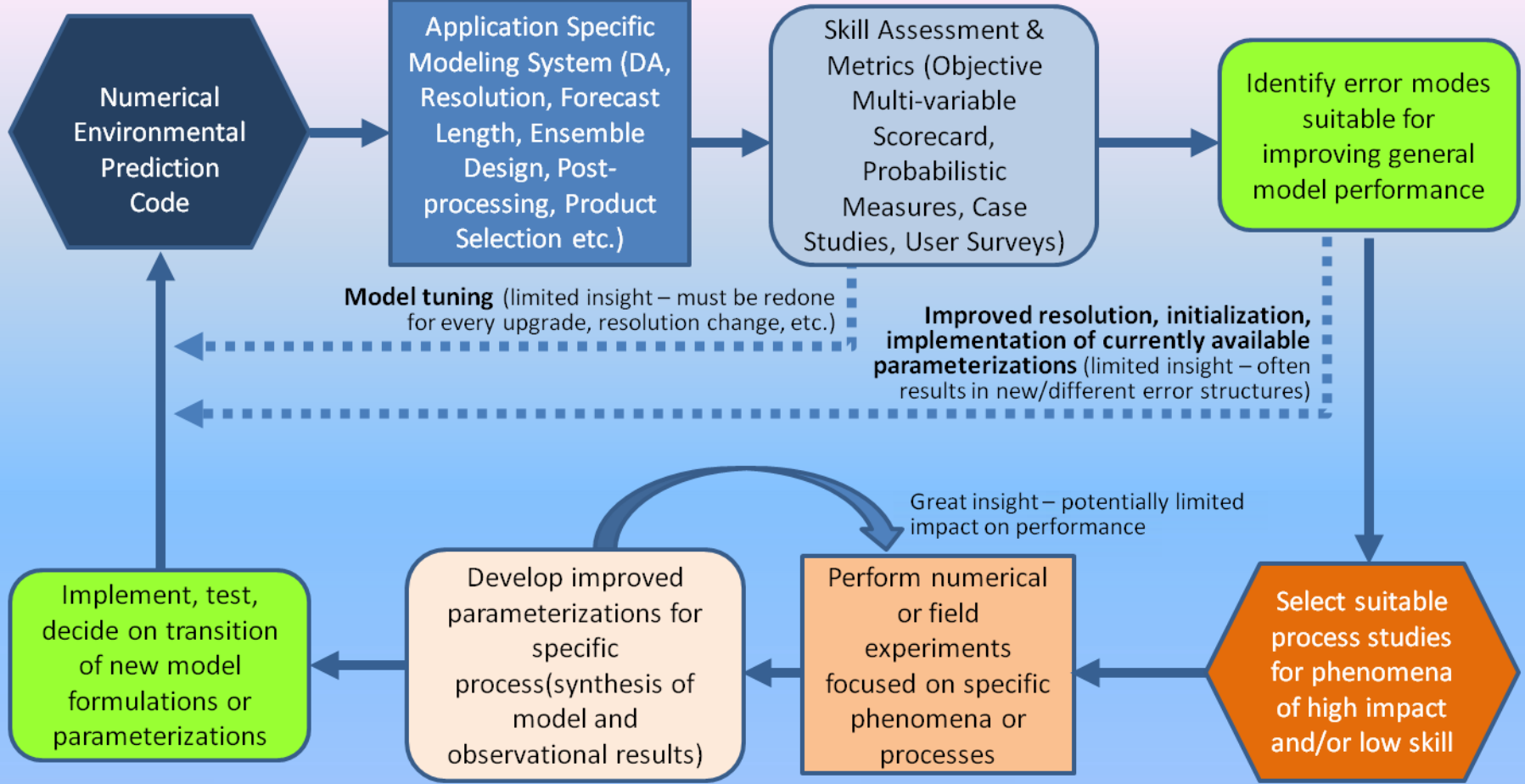
**5-7-day  
HFIP/NRL Ensemble**

**30-day NPS Research  
Forecasts to JTWC  
Ensemble Probabilities**

**Seasonal Track  
Frequency/Probability  
based on ISI Predicted  
state**

# Model Improvement through process studies

## OPERATIONS



After Jakob, BAMS2009



# Process-oriented Field Studies

**Overarching DYNAMO Goal:**  
To expedite the progress of advancing our understanding of **MJO initiation** processes and improved simulation and prediction of the MJO

**LASP Goals:**

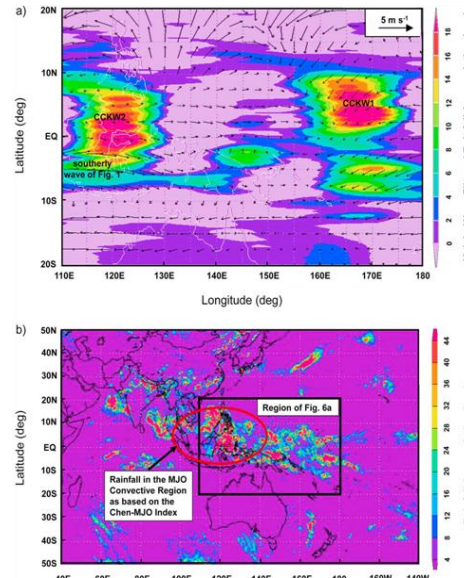
- A better understanding of physical processes and numerical representation of coupled modes.
- Better operational prediction in the maritime tropics and subtropics.



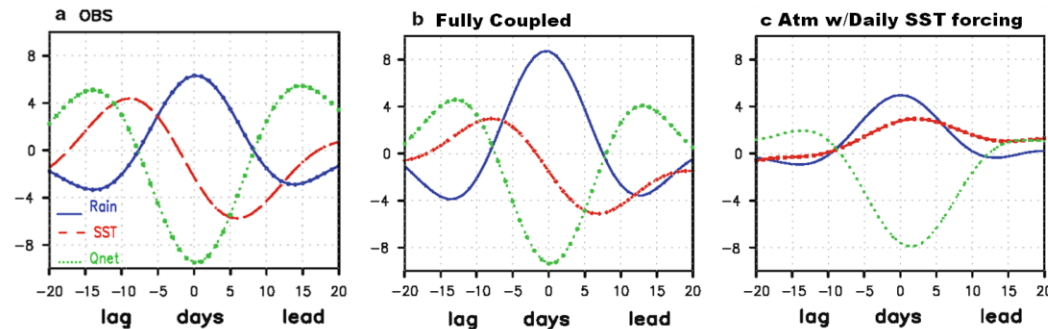
# Process-oriented Field Studies

## What's after DYNAMO?

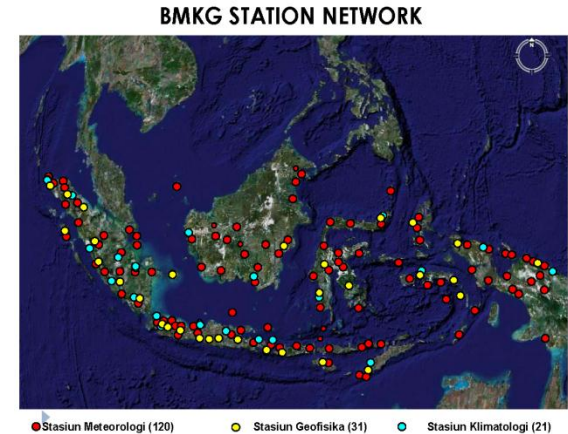
- Monsoon Mission?
- Year of Maritime Continent?
- BSISO/ MISO, MC Prediction Barrier, etc.?
- Link to Tropical Cyclone sub-seasonal variability?
- Link to mid latitudes or arctic?



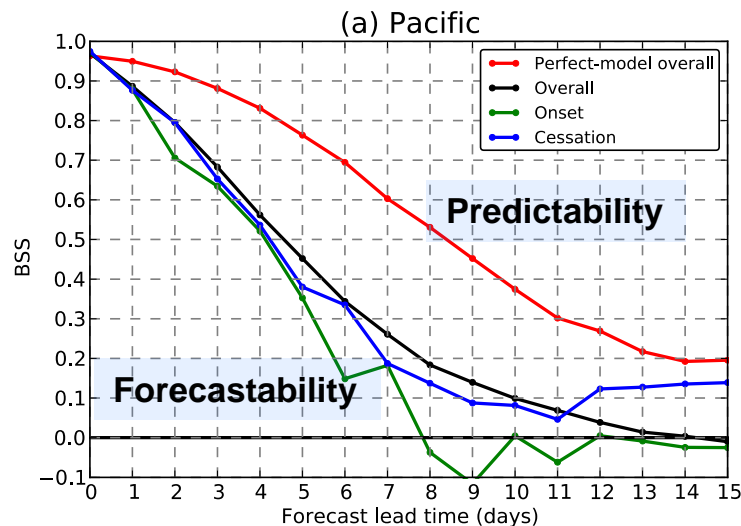
Ridout and Flatau, JGR 2011



Sharmilla et al. 2013

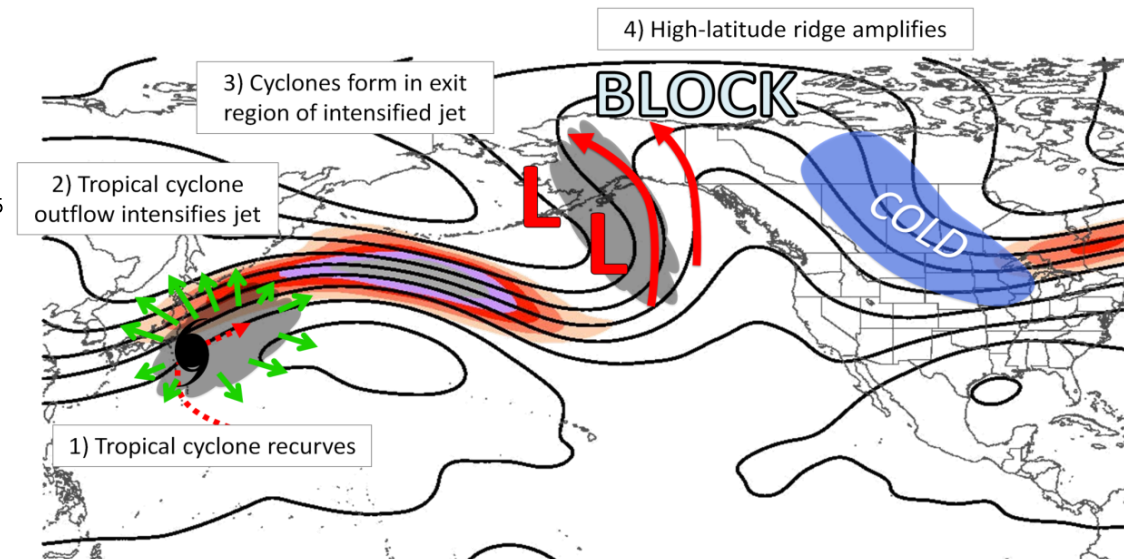
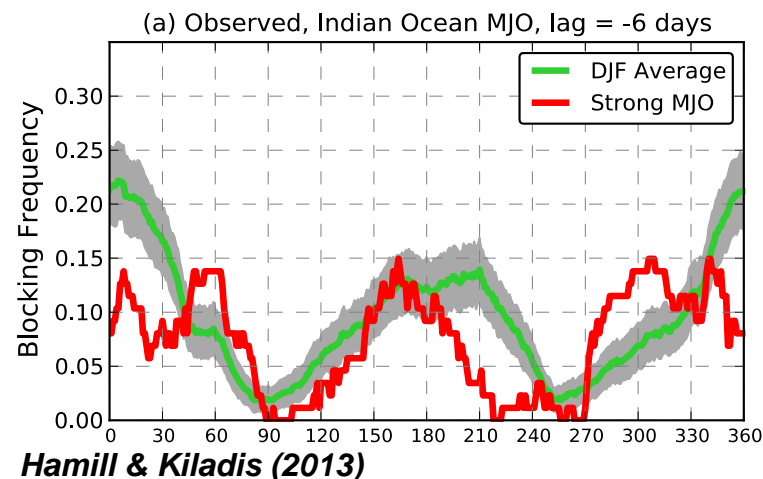


# Change in EPAC and ATL blocking frequency after strong Indian Ocean MJO



Shaded areas are confidence 5/95% confidence intervals.

Change in blocking frequency in the east Pacific and Atlantic observed with a lagged phase after a strong Indian Ocean MJO. Day +6 GEFS replicates this to some degree; however, there is still a 3-4 day lag in realized skill.



Tropical cyclone outflow characteristics impact the type of midlatitude response:

- i) Circular outflow pattern and ridge amplification
- ii) Linear outflow pattern and jet elongation

The midlatitude response impacts the potential for blocking, the longitude of blocking, and the intensity of the block

**Archambault et al. (2013)**



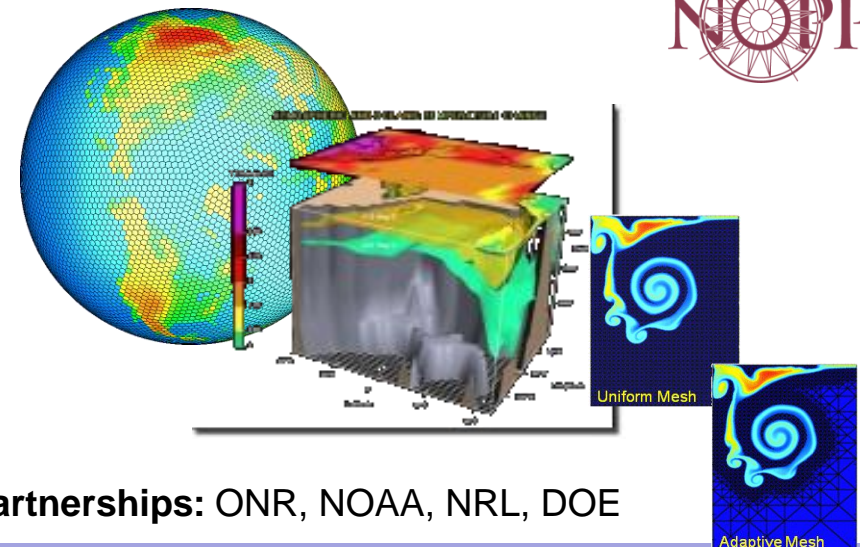
# FY13 NOPP Topic: Advancing Air-Ocean-Land-Ice Global Coupled Prediction on Emerging Computational Architectures

**Objective:** To develop a significantly improved capability to simulate and predict the coupled global air-ocean-land-ice ocean system at eddy-resolving spatial scales and ISI timescales in a computationally efficient and operationally affordable architecture towards real-time forecast capability.

**Technical Approach:** An interdisciplinary team of computer scientists, oceanographic and meteorological scientists, numerical methods experts, and software engineers will develop approaches to massive fine-grain parallelism suitable for data-assimilating coupled forecasts of environmental conditions. Automated code refactoring and emerging technologies for many core accelerators will be assessed and portability to multiple platforms is desired.

**Expected Outcome:** Demonstrated improved scalability to thousands of nodes, with computational accuracy and run-time efficiency relative to legacy architectures within the Navy, NOAA, and DoE's coupled global weather and climate models.

<http://coaps.fsu.edu/aoli/projects>



**Partnerships:** ONR, NOAA, NRL, DOE

# Successful Proposals

## **Accelerated Prediction of the Polar Ice and Global Ocean (APPIGO)**

Chassignet, Eric and Bozec, Alexandra - Florida State University  
Campbell, Tim and Wallcraft, Alan- NRL, Stennis Space Center  
- U Miami

Hunke, Aulwes, and Jones - LANL  
Kirtman, Ben and Iskandarani, Mohamed

## **An Integration and Evaluation Framework for ESPC Coupled Models**

DeLuca, Cecelia - University of Colorado  
Kirtman, Ben - University of Miami  
Jacob, Robert - University of Chicago  
Chassignet, Eric and Bozec, Alexandra - Florida State

Kinter, Jim - George Mason University/ COLA  
Campbell, Tim – NRL Stennis Space Center  
Wilson, Paul - University of Wisconsin  
Vertenstein, Mariana – NCAR

## **RRTMGP: A High-Performance Broadband Radiation Code for the Next Decade**

Mlawer, Eli – Atmospheric & Environmental Research, Inc.  
Eaton, Brian – NCAR  
Monterey

Pincus, Robert – University of Colorado  
Reynolds, Carolyn and Liu, Ming – NRL

## **NPS-NRL-Rice-UIUC Collaboration on Nonhydrostatic Unified Model of the Atmosphere (NUMA) Coupled Models on Many- Core Computer Architectures**

Wilcox, Lucas and Giraldo, Frank – Naval Postgraduate  
Campbell, Tim – NRL Stennis Space Center

Warburton, Tim – Rice University  
Klößner, Andreas - University of Illinois, UC

<http://coaps.fsu.edu/aoli/projects>

# International Sea Ice Prediction Research Network



Julienne Stroeve, Cecilia Bitz, Hajo Eicken, Larry Hamilton, Helen Wiggins, Elizabeth Hunke, Phil Jones, Adrienne Tivy, Jim Overland, Muyin Wang, Jenny Hutchings, Walt Meier

and dozens of international collaborators



# Prediction Network

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- Evolve the SEARCH Arctic Sea Ice Outlook to an International Sea Ice Prediction Network
- Prediction at seasonal to interannual timescale, synergy with climate projections
- Collaboration of observers, modelers, physicists, and social scientists
- Focus on public engagement and advancing the science of sea ice prediction



# Prediction Network Goals for Modeling

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- To determine the predictability of Arctic sea-ice at regional and local level
- To advance sea ice prediction methods
- To improve sea ice models for prediction
- To determine how we can best observe the Arctic system to inform sea ice prediction
- To make sea ice forecasts with uncertainty estimates
- Link research and operation efforts

# Action Team Mechanism

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- Kick-off meeting in late-winter 2013/spring 2014
- Monthly virtual meetings
- Web resources
- Email lists
- Meet in Breckenridge next year in evening/extra day?
- suggestions?

**We want your input!**

**Prediction experiments and methods, observations,  
metrics, communication styles, etc**

# The High Impact Weather Prediction Project (HIWPP)

## HIWPP Goals

To improve the United States' operational global numerical weather prediction systems. In the next two years we seek to improve our hydrostatic-scale global modeling systems and demonstrate their skill. In parallel, we will accelerate the development and evaluation of higher-resolution, cloud-resolving (non-hydrostatic) global modeling systems that could make a quantum leap forward in our nation's forecast skill, targeting 2020 and beyond.

- A 2-Year \$12.905M Project, which begins Fall, 2013
- Five Thrusts:
  - Global hydrostatic ensembles for medium-range (0-32 day) forecasts (with enhanced resolution, physics & assimilation)
  - Accelerated development of a global non-hydrostatic (0-14 day) prediction system
  - A services framework focused on the timely and accurate delivery of global weather data and related earth system information
  - Incorporating nested regional Hurricane WRF models into the NCEP NMM-B (and other) modeling system
  - Augmenting the National Multi-Model Ensemble (NMME) capability for seasonal (long-range weather) prediction

# Towards a National ESPC

Federal partnering to improve adoption of research breakthroughs from a wider community into operations.

HFIP, NUOPC, and NMME have shown great benefit to operational National forecast skill for short/medium/seasonal range weather, and should be continued and expanded.

The goals of the ESPC Inter-Agency Project indicate that R2O should:

- be extended to transition of regional and global air-sea-wave-ice coupled models leveraging community models
- improve adoption of ESMF standards through the ESPS initiative and CMA committee
- Extend/continue the multi-model ensemble approach at sub-seasonal and seasonal scales through an NMME follow-on for operationalizing this research.

A National ESPC will provide the next generation of operational environmental prediction services for 0-16 days and 3-9 Months, a major challenge is still to address the sub-seasonal (weeks 2-12) where skill is lowest, and extend skill globally to Mid-Latitudes and Arctic.



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# Discussion

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# Back-up slides

# Where We Are Today

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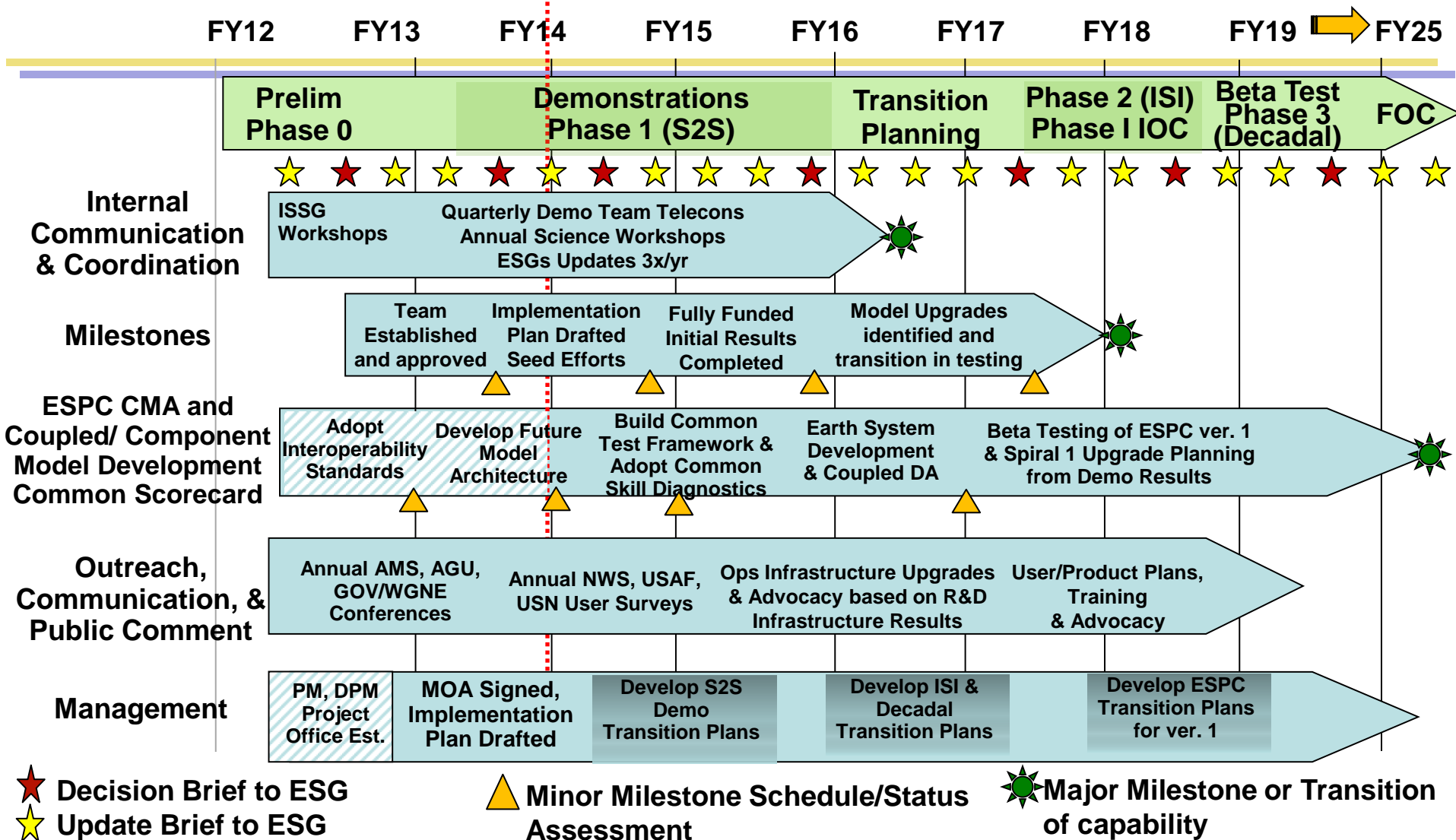
- Updated MOA signed by all partners (Navy, NOAA, Air Force, NASA, DoE, NSF) in April 2013
- Implementation Plan in draft modeled after the Initial Operational Capability of the NUOPC North America 0-16 Day Unified Ensemble in January 2011 (Navy, Air Force, NOAA, Canada)
- Software architecture and interoperability standards part of latest release of the Earth System Modeling Framework
- Demonstration Projects established
- Initial discussions with ongoing related inter-agency collaborations (HFIP, NUOPC, NMME)
- ONR/NOAA NOPP project on massively parallel fine grain computing for ESPC models and NOAA/ONR project on High Impact Weather Prediction (HIWPP) initiated for 2014 starts

# FY14 Plans

- **Continue Navy-ESPC System Implementation**
  - Test Coupled NAVGEM-HYCOM-CICE
- **Assess suitability of NMME to shorter timescales, higher resolution, additional output fields, and (global) areas of interest**
- **Develop community collaborations among Federal Sponsors and Numerical Prediction Developers**
  - ESPC Demonstration projects
  - NOPP Topic on Global Coupled Models on Massively Parallel Computers
  - Component Air-Sea-Wave-Ice models and Data Assimilation
  - Improve Coupled Ensemble construction and validation metrics
- **Continue/extend NUOPC/ESPC CMA and Interoperability**
  - Expand ESPS for Global Coupled Models, new grids, fault-tolerant Ensembles
  - Integrate capabilities in ESMF, NUOPC and CESM Drivers towards ESPS goals
- Working Groups on ESPC Demonstrations, Managed Ensembles, Improved Computational Efficiency, Physics Interoperability, Common Modeling Architecture, and the High Impact Weather Improved Prediction Project (HIWIPP)

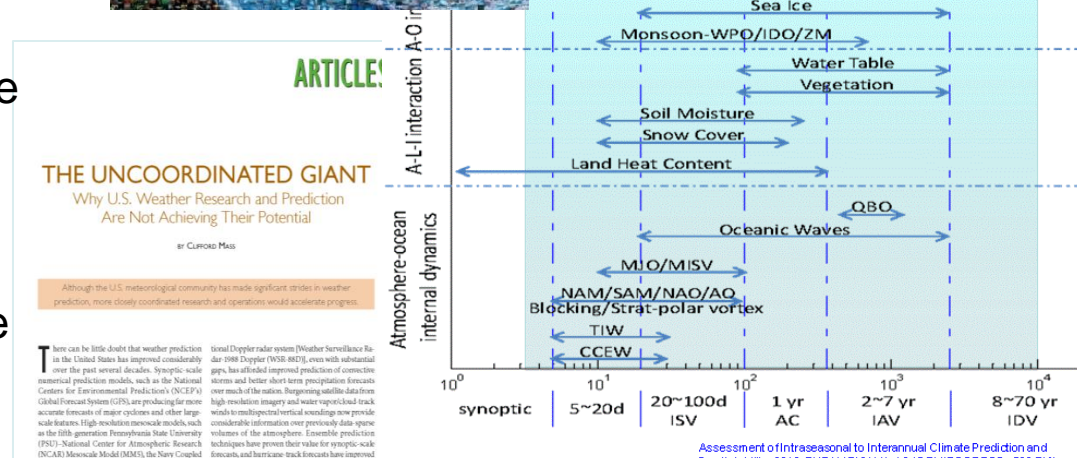
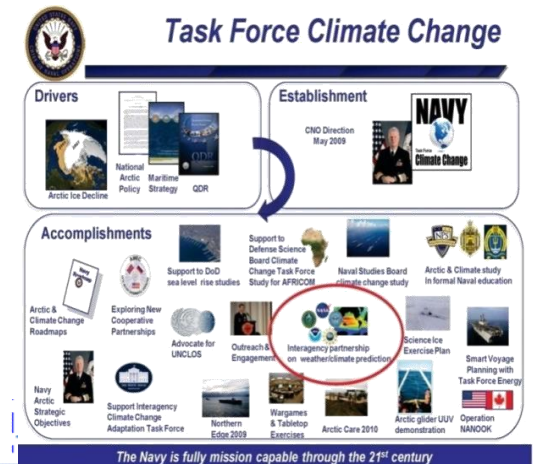
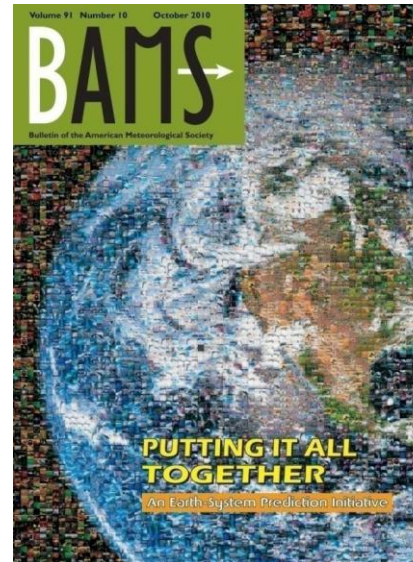


# ESPC Schedule

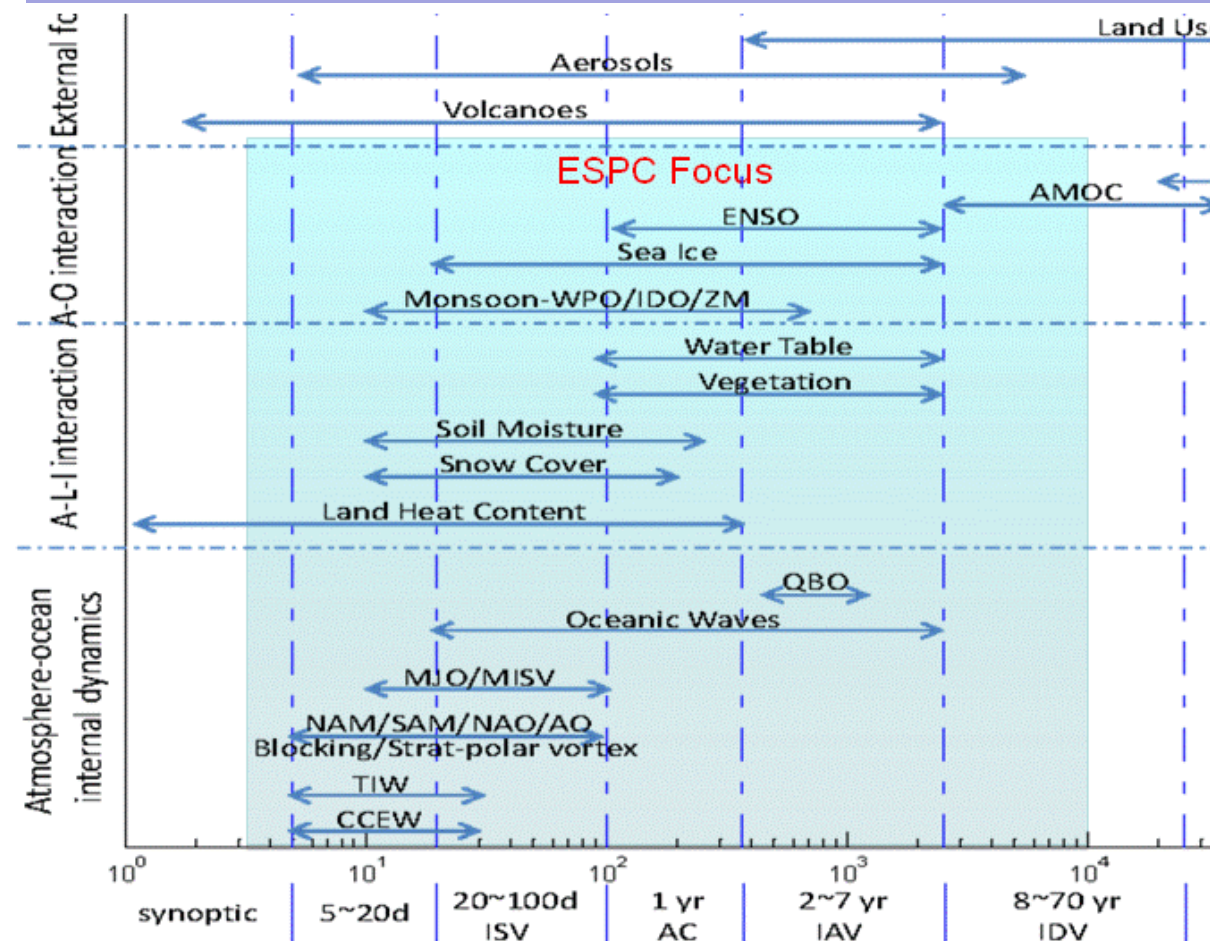


## Community and Agency Calls to Action

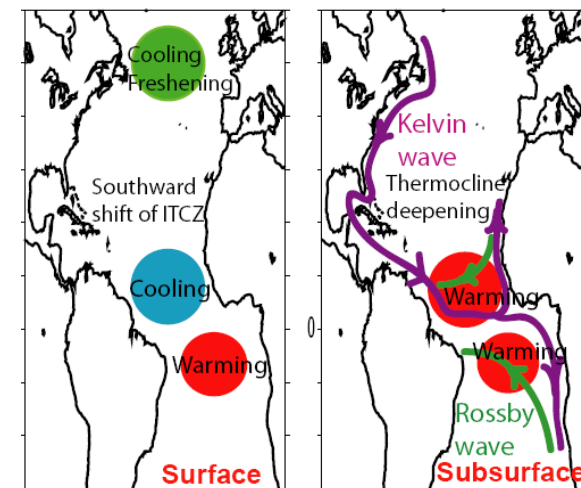
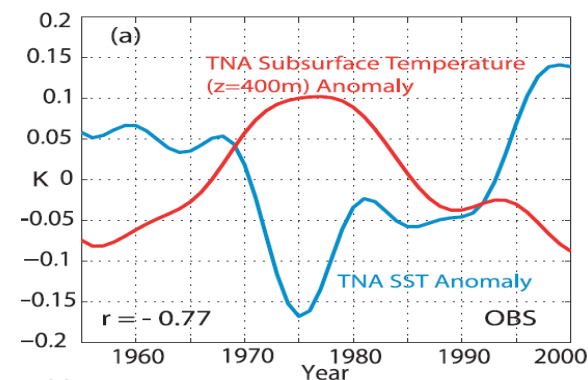
- An Earth-System Prediction Initiative for the Twenty-First Century (Shapiro et al. 2010)
- Collaboration of the Weather and Climate Communities to Advance Subseasonal-to-Seasonal Prediction (Brunet et al. 2010)
- Assessment of Intraseasonal to Interannual Climate Prediction and Predictability (Weller, 2010)
- Arctic Security Considerations and the U.S. Navy's Roadmap for the Arctic (Titley and St. John, 2009)
- The Uncoordinated Giant: Why U.S. Weather Research and Prediction are not Achieving their Potential (Mass, 2006)



# Sources of Extended Range Predictability: Subseasonal, Intraseasonal and Interannual (ISI) Timescales



Assessment of Intraseasonal to Interannual Climate Prediction and Predictability, 2010, THE NATIONAL ACADEMIES PRESS • 500 Fifth Street, N.W. • Washington, DC 20001



R. Zhang, 2007

# What Do We Gain from Multi-Model Ensemble Prediction?

## ***Uncertainty in initial state: members with different initial conditions***

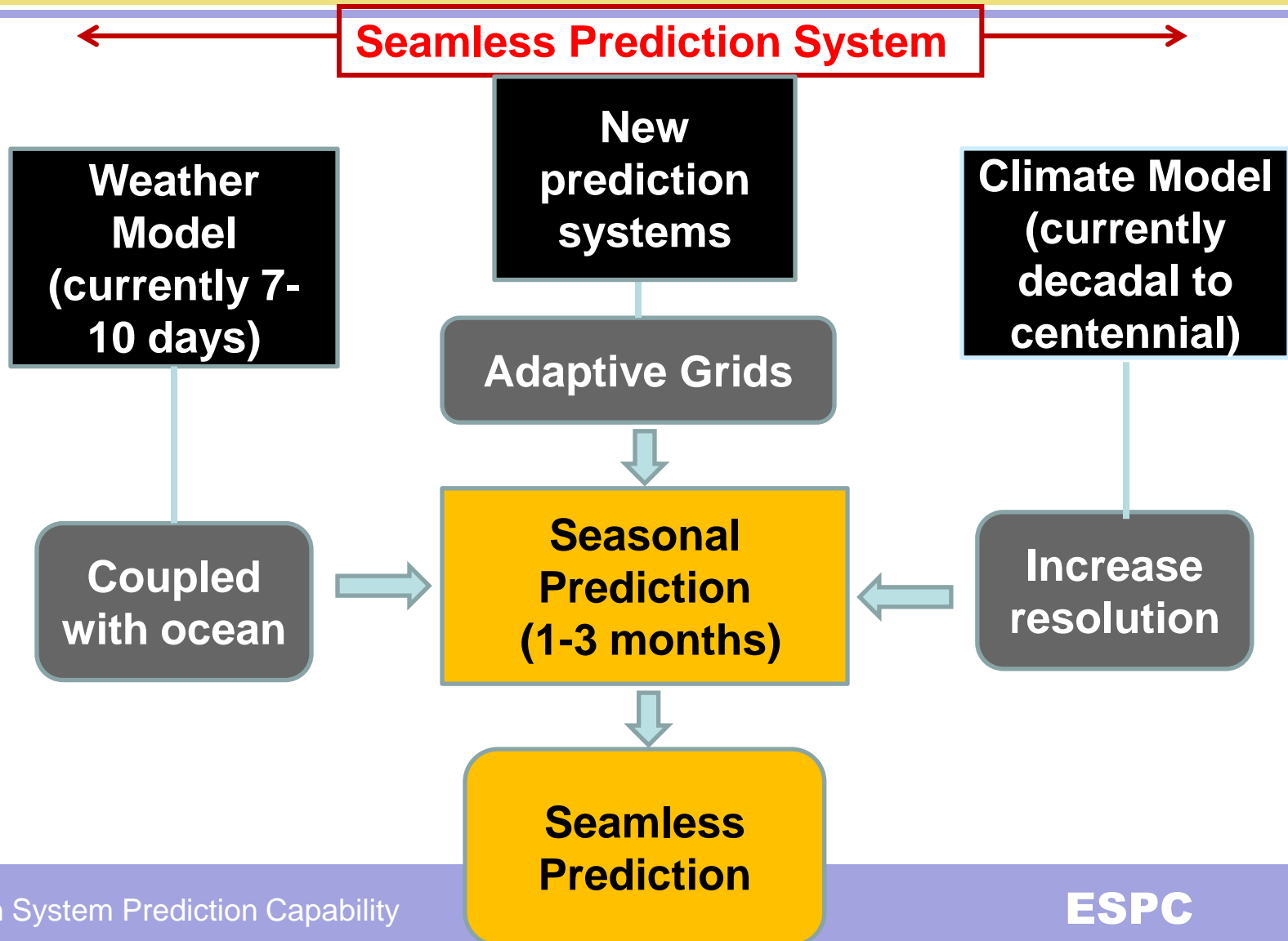
- Methods to perturb initial conditions: Parallel data assimilation cycles, rapidly growing linear perturbations, Kalman filter methods
  - Ensemble Transform (ET, McLay et al. 2008; banded ET, McLay et al. 2010): Transform 6-h ensemble perturbations to be consistent with analysis error estimates. Because it is a cycling scheme, model perturbations impact initial perturbations.

## ***Uncertainty in model formulation: utilize varying models***

- Methods to include model uncertainty: Different forecast models, different sub-grid-scale parameterizations, stochastic forcing, boundary forcing (SST, land)
  - **Multi-model ensembles**
    - Parameter variations
    - Stochastic convection, stochastic kinetic energy backscatter, diurnal SST

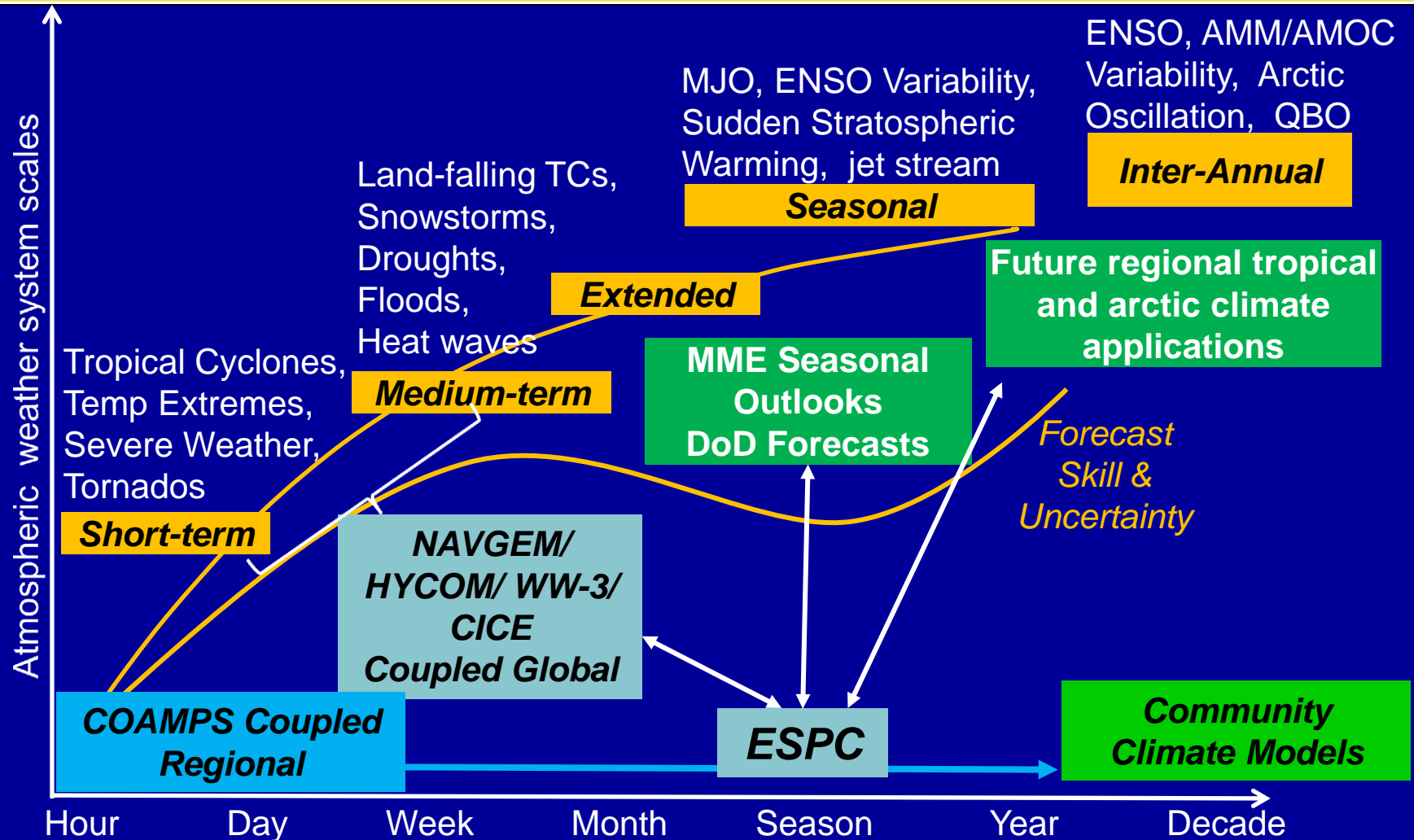


# Strategy





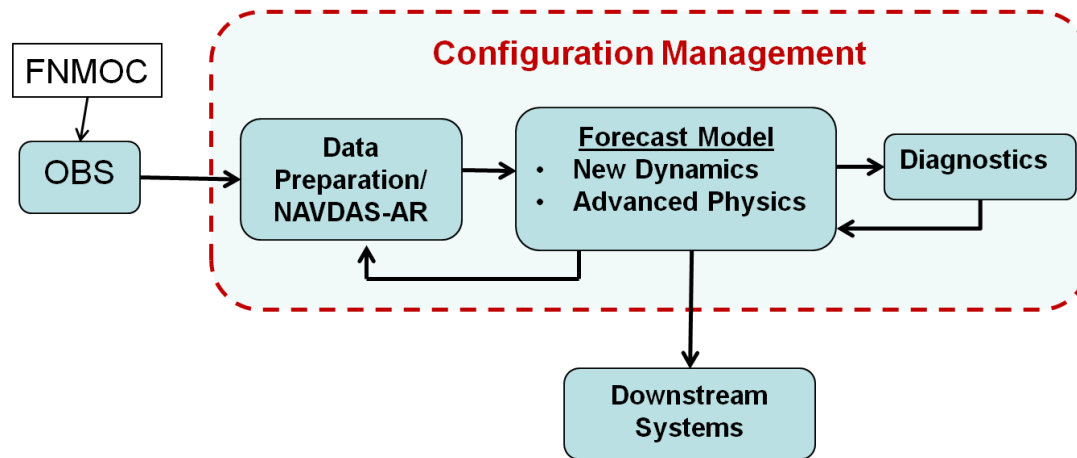
# Regional to Global Prediction



# Navy Global Environmental Model

## NAVGEN (Operational March 2013)

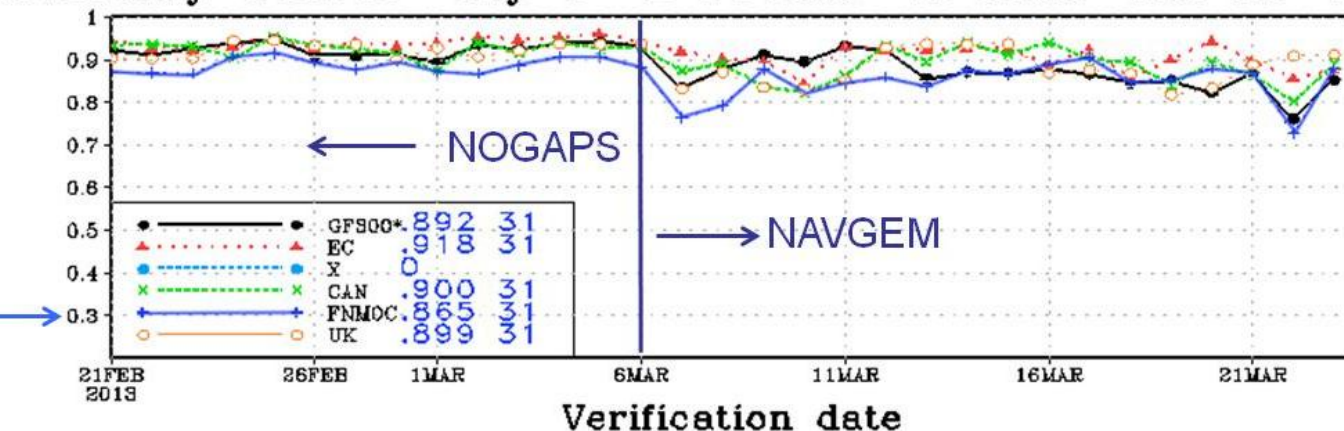
- A new Navy global prediction system developed by NRL and tested on NRL, FNMOC, and DSRC computer systems
- Improved dynamics (SI/SL), physics, and data assimilation (Hybrid ENKF/4DVAR) under development
- Chosen as the Bridging Strategy for the Navy global forecast system toward ESPC



NAVGEN is the first operational global model with SL/SI dynamic core in the nation

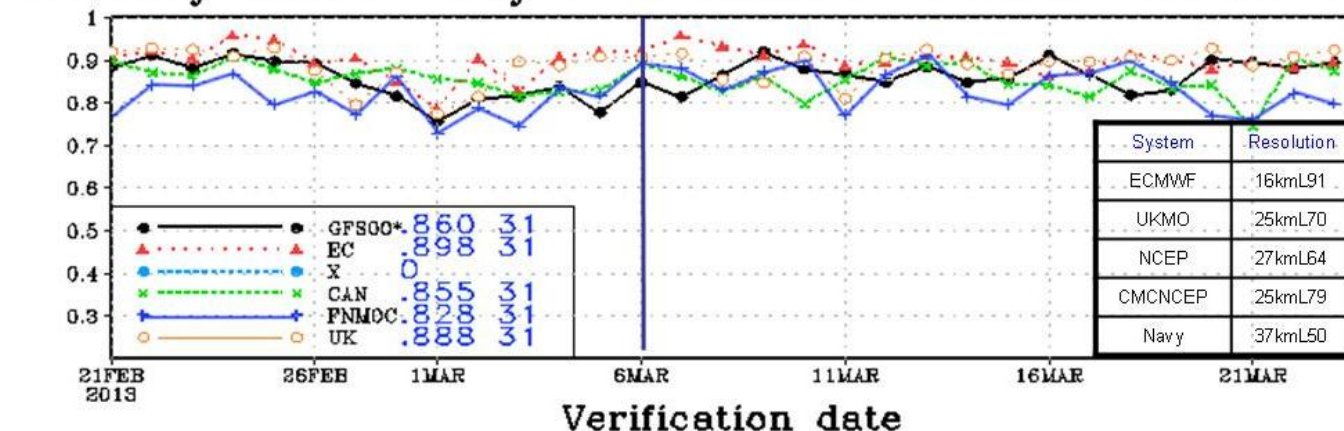
# Recent Model Performance Comparisons

Anomaly Correl day 5 Z 500mb n hem lat 20-80



System	Resolution
ECMWF	16kmL91
UKMO	25kmL70
CMC	25kmL79
NCEP	27kmL64
Navy	37kmL50

Anomaly Correl day 5 Z 500mb s hem lat 20-80



# ESPC: Coupling Infrastructure

## Project Major Milestones for FY12-15

Coupling infrastructure and interoperability layer extension across all ESPC components												
	FY13				FY14				FY15			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Implement ESMF/NUOPC based coupling infrastructure that integrates ATM, OCN, WAV, ICE, & LND models and a mediating (flux-exchange) layer.	<b>S</b>			<b>D</b>				<b>C</b>				
Implement & test inter-model flux exchange (ATM/OCN/ICE)	<b>S</b>									<b>C</b>		
Implement & test inter-model flux exchange (ATM/OCN/WAV)	<b>S</b>									<b>C</b>		
Implement & test inter-model flux exchange (ATM/OCN/LND)	<b>S</b>									<b>C</b>		

- **S – Start, D- Demonstration/ Evaluation, C-Complete**
- **Infrastructure Implementation:** 60% complete; currently testing (w/o flux-exchange layer) in COAMPS;
- **Model Integration:** 30% complete; functional ESMF/NUOPC interface implemented in NAVGEM, HYCOM, CICE; current testing with NUOPC generic driver; integration into ESPC system next step;
- **Flux Exchange:** 10% complete; “pass-through” version ; flux calculations in progress; fractional cell approach next step;

# Global NAVGEM / HYCOM Loose Coupling

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**Objective** – Investigate interaction of NAVGEM / HYCOM in a controlled manner that limits the feedback process, and thus facilitates identification of system biases and physical deficiencies.

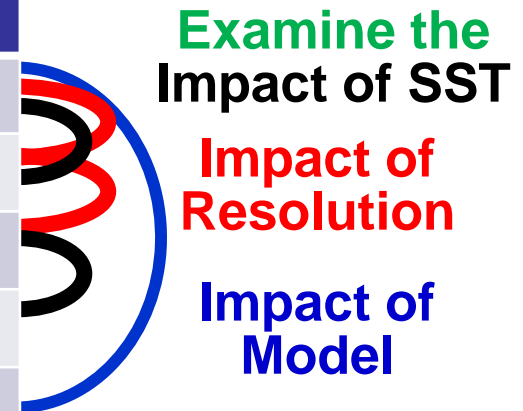
**Methodology** – Alternating sequences of NAVGEM and HYCOM hindcasts are carried out in which NAVGEM (HYCOM) is run using boundary data from the preceding HYCOM (NAVGEM) run.

**Initial Case** – 30-day runs beginning on 1 November, 2011 (chosen for the availability of oceanic and atmospheric data for validation from the DYNAMO Experiment).



# Coupled Regional Mesoscale Model Experimental Design

Name	Model	Resolution	SST
C45F	COAMPS	45km	Fixed
C45O	COAMPS	45km	Observed
C27F	COAMPS	27km	Fixed
C27O	COAMPS	27km	Observed
N37F	NAVGEN	37km	Fixed



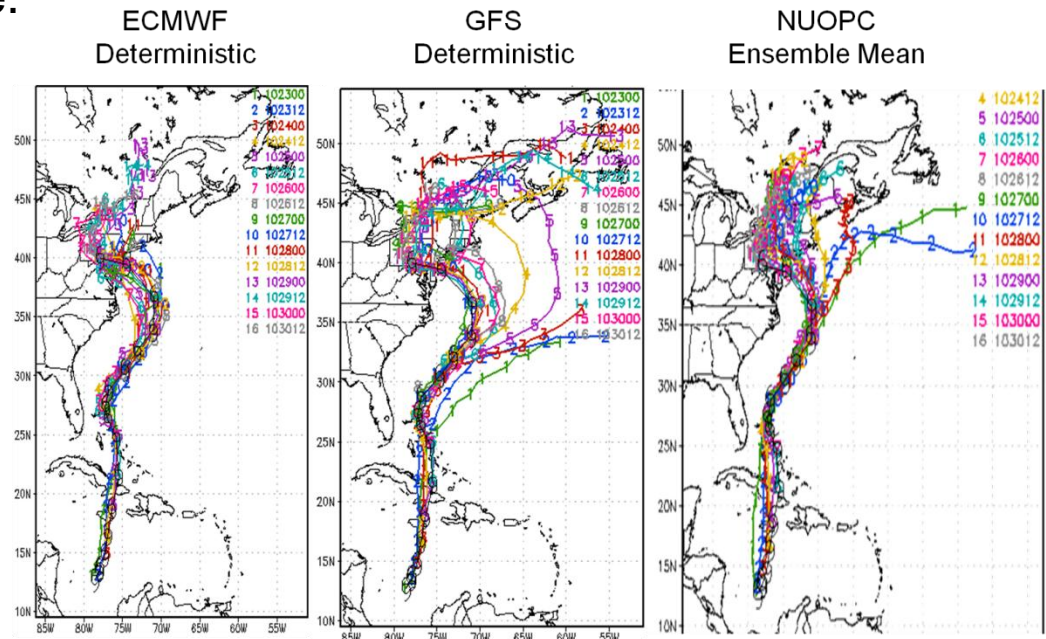
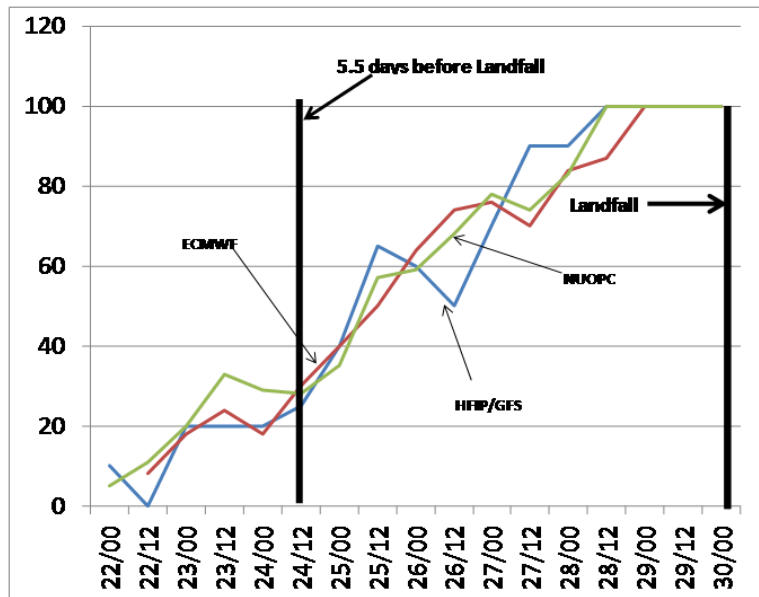
*Fixed SST: NCODA SST analysis on 31 October held fixed through integration*  
*Observed SST: NCODA SST analyses updated every 24 hours.*

## Verification

- **NOGAPS analysis (42 km)**
- **NASA Tropical Rainfall Measuring Mission (TRMM)**
- **NOAA OLR**

# Communicating Ensemble-Based Information Uncertainty, Risk and Probability

Blocking pattern and uncertainty in the observed initial conditions resulted in a bifurcated track scenario in the GFS ensemble with one cluster of GEFS members moving the storm eastward and another cluster westward towards the US East Coast. Several other models locked onto the westward track earlier and all forecast models indicated probable landfall by about a 5 day lead time. Communicating variance about the mean and collapsing a 30-50 member ensemble down into meaningful guidance continues to be a challenge.



# The High Impact Weather Prediction improvement Project

## High Impact Weather Prediction Project (HIWPP) Executive Oversight Board

Chair: John Cortinas (OWAQ)  
Members: Bob Atlas (AOML), Simon Chang (NRL), Kevin Kelleher (GSD), Bill Lapenta (EMC), Sandy MacDonald (ESRL), John Murphy (OST), Bill Neff (PSD), V. Ramaswamy (GFDL)

Technical POCs,  
Lead Organization

Project Manager:  
Tim Schneider, ESRL/GSD

Executive Secretariat/Business Manager:  
Steve Warren, OWAQ

### Hydrostatic Global Models

**Assimilation Enhancement**  
POC: Jeff Whitaker, ESRL

**Ensembles and Retrospective Runs**  
POC: J. Whitaker/T. Hamill, ESRL

**GFS**  
POC: Yuejian Zhu, NCEP

**FIM**  
POC: Stan Benjamin, ESRL

**NAVGEM**  
POC: Melinda Peng, NRL

### Test Program

**Visualization and Extraction via NEIS**  
POC: Jebb Stewart, ESRL

**Verification Methods**  
POC: Steve Weygandt, ESRL

**Real Time IT Operations**  
POC: TBD, ESRL

### Non-Hydrostatic Global Models

**Assimilation/Ensemble/Physics**  
POC: J. Whitaker/T. Hamill, ESRL

**MPFG/GPU Optimization**  
POC: Mark Govett, ESRL

**NIM**  
POC: Jin Lee, ESRL

**MPAS**  
POC: Bill Skamarock, NCAR

**NMMB**  
POC: Zavis Janjic, NCEP

**HIRAM**  
POC: S. J. Lin, GFDL

**Navy Non-Hydrostatic Model**  
POC: Jim Doyle, NRL

**Moving Hurricane Nest**  
POC: S. "Gopal" Gopalakrishna, AOML

**NMME Expansion**  
POC: Jin Huang, CPC

5 September 2013